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Scientific and Technical Information Office

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A PILOT EVALUATION OF TWO G-SEAT CUEING SCHEMES

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SUMMARY

A fixed-base simulation study was conducted to obtain pilot opinion data on the ability of the G-seat to simulate aircraft acceleration cues. The G-seat consisted of a seat containing 23 pneumatic cells, 14 in the seat pan and 9 in the seat back. Two cueing schemes were used. One was based upon body position changes and the other upon skin pressures. Five pilots rated and commented on the G-seat operation during the simulation of four simple and one complex maneuvers.

The pilots' responses to the Post Maneuver Questionnaire indicated that they perceived the G-seat operation in terms of the following cues: back and buttocks pressures, body vertical and longitudinal position changes, head rotations, seat belt and shoulder strap pressures, and concentration or dispersion of back or buttocks pressures. It is obvious that the G-seat cannot control these cues independently and that some are mutually exclusive. In this study the pilots commented on the conflict between buttocks pressure and body position, and buttocks pressure and the dispersion or concentration of buttocks pressures for the vertical accelerations. The pilots' comments indicate that they were quite aware of these and other conflicts. A comparison of the comments on the pullout and pushover maneuvers with the thrusting maneuver indicates that rate of acceleration onset adds another dimension, frequency response of the various cues, to the conflicts created by the G-seat. The conflicts created among the various G-seat acceleration cues must be responsible, to a large extent, for the individual differences found in this study.

INTRODUCTION

The traditional approach to aircraft simulator design has been to attempt to match the physical stimuli generated by the simulator with those produced in actual flight. A better match would supposedly produce more "fidelity." In fact, the term fidelity usually referred to the quality of the match between simulated and flight produced physical stimuli, and only vaguely referred to the psychological effects of simulation cues.

Unfortunately, the traditional approach poses problems. Simulator subsystems, such as visual systems or control loaders, operate only as close approximations to the actual aircraft cues and are used in the hope that these approximations do not seriously affect pilot perception and performance. Other simulator subsystems, such as motion systems, are even more limited in their ability to reproduce high-fidelity cues. In operation, the motion system operating commands are filtered before they enter the motion system hardware. Regarding linear accelerations, the filtering process attenuates the low-frequency acceleration commands (e.g., < 1.5 rad/sec), leaving the motion

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system to reproduce essentially the high-frequency acceleration cues. Motion system size affects the filtering process for linear accelerations in that as size increases, the motion system operational bandwidth can extend to lower and lower frequencies. Eventually, though, cost constraints limit motion system size and bandwidth, whereby further motion system improvements, primarily in the higher frequency range, are handled by changes in computer hardware and software. The net result has been that reasonably priced motion systems can only create high-fidelity and high-frequency linear acceleration cues and that motion systems that reproduce high-fidelity, low-frequency cues have been, and will continue to be, quite large and, therefore, quite costly. Perhaps, though, instead of designing a motion system to meet certain physical criteria (i.e., moving the simulator cab at a certain acceleration), a feasible and less costly approach to cueing low-frequency accelerations might be to design simulation hardware to psychological criteria (i.e., creating a perceptual event similar to whole body acceleration).

The G-seat, a proposed means of cueing low-frequency acceleration, represents one attempt at designing simulation hardware to psychological criteria. The G-seat attempts to induce the illusion of acceleration within a pilot by creating those somatic stimuli, such as skin pressure changes and body position cues, that are thought to be closely associated with a pilot's perception of whole body acceleration. The premise is that the illusion can be easily induced, since it is thought that somatic cues are intimately linked with a pilot's perception of acceleration. Operationally, as the simulator pilot puts his vehicle through a variety of maneuvers, G-seat back and pan contours change shape in accordance with guidelines in a computer software program (i.e., G-seat logic or cueing scheme). Such contour changes, hopefully, stimulate the pilot's perceptual system to create the illusion of acceleration. Initially, the G-seat was conceived and designed to cue sustained (i.e., low-frequency) accelerations, but recently others have discussed using it to cue onset (i.e., high-frequency) accelerations. However, the purpose of this study was not to compare how well the G-seat could cue low-frequency versus high-frequency accelerations, but to determine which of two G-seat logics produces the most appropriate acceleration cues.

At present, there is little organized knowledge concerning how a G-seat should be programmed to effectively cue acceleration. Present cueing schemes have proposed that the G-seat be used to cue acceleration in all six dimensions of aircraft motion (i.e., roll, pitch, yaw, longitudinal, lateral, vertical) (ref. 1). Such schemes have six unique sets of complex seat contours with each set designed to cue acceleration in a certain dimension (e.g., roll). Neither the concept of using a G-seat to cue all six dimensions of motion nor the specific means of cueing a certain dimension have been subjected to a rigorous empirical evaluation.

This study makes a systematic empirical evaluation of two contrasting types of G-seat logic to determine which of those logics (or some combination/derivative of them) produce the most appropriate acceleration cues. In the study, both logics were designed and tested regarding how well each cued perception of vertical (Z), longitudinal (X), and roll accelerations (fig. 1). The philosophies behind the design of each logic will be discussed subsequently in the Method section and in appendix A.

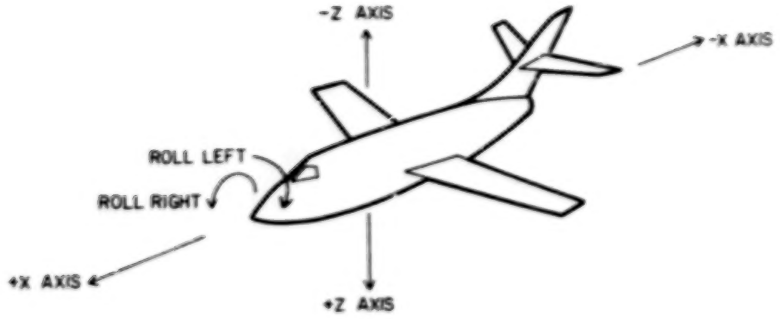


Figure 1.– Sign conventions for vertical, longitudinal, and roll accelerations.

METHOD

Apparatus

The G-seat, shown in figure 2 with a few of its seat pan pneumatic cells exposed, contained 23 pneumatic cells as diagrammed in figure 3, 14 in the seat pan and 9 in the seat back. Each cell was individually controlled by the digital simulation computer and was capable of expanding to any point within 7.0 cm (2.75 in.) of its fully deflated position. For further information regarding G-seat dimensions and physical performance characteristics (see figs. 4 and 5 and ref. 3).

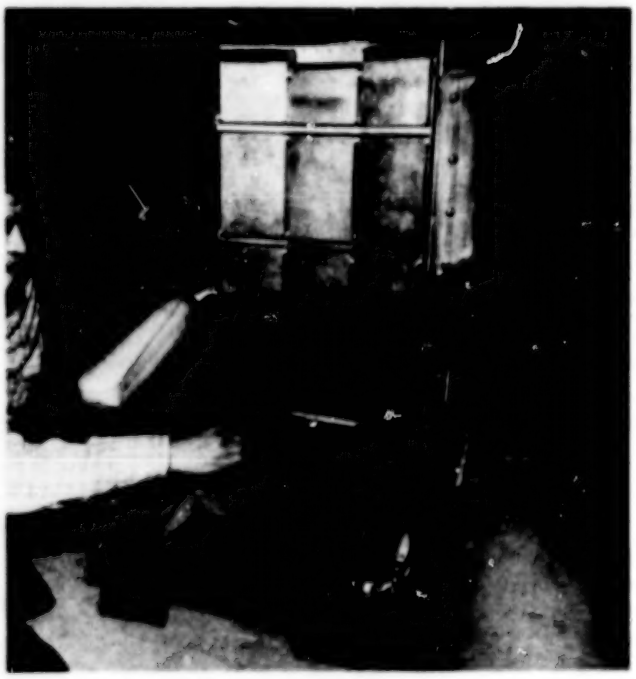


Figure 2.– G-seat photograph.

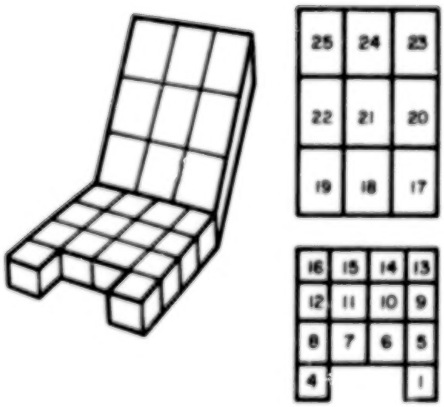


Figure 3.– G-seat cell diagram.

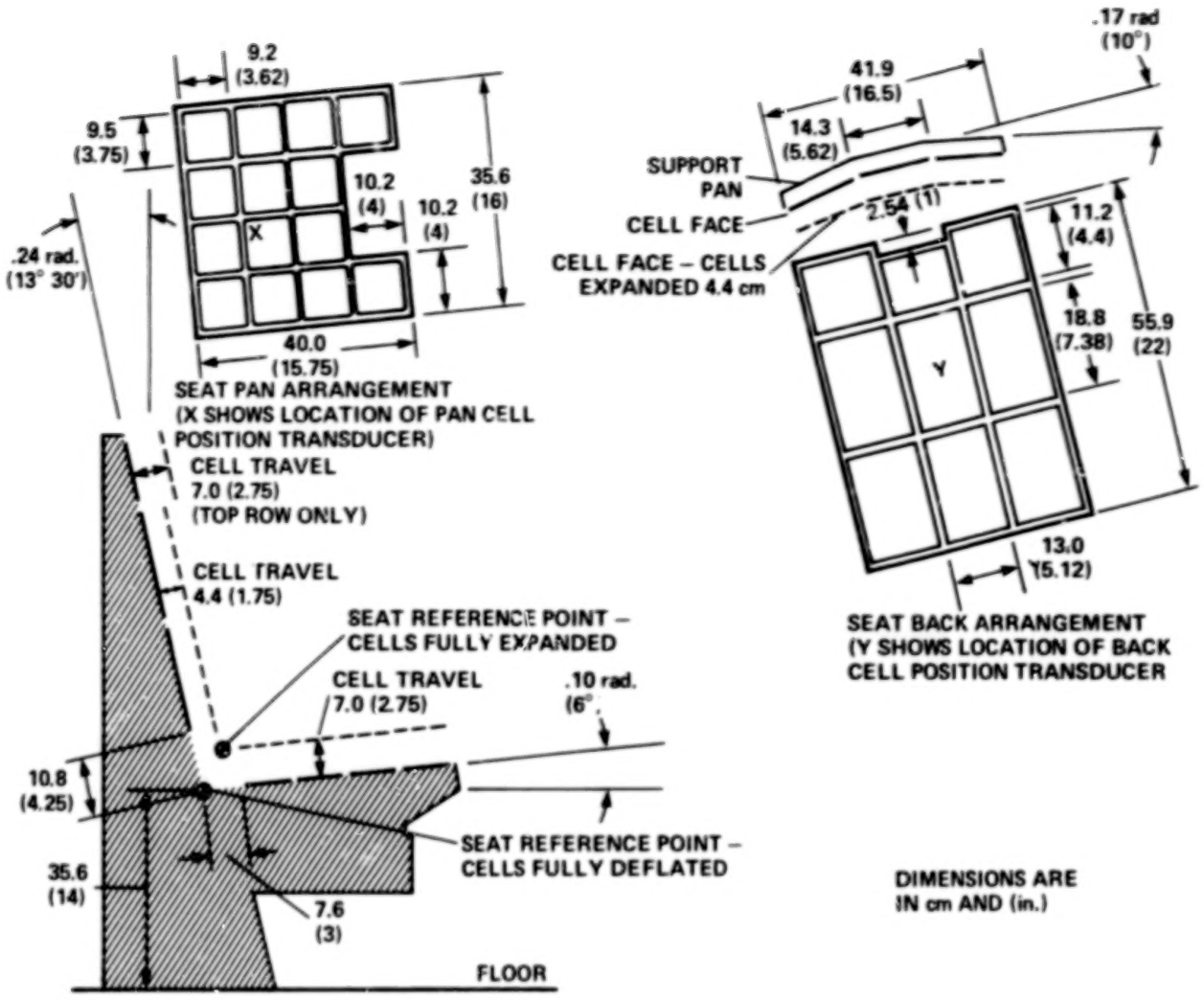


Figure 4.– G-seat dimensions.

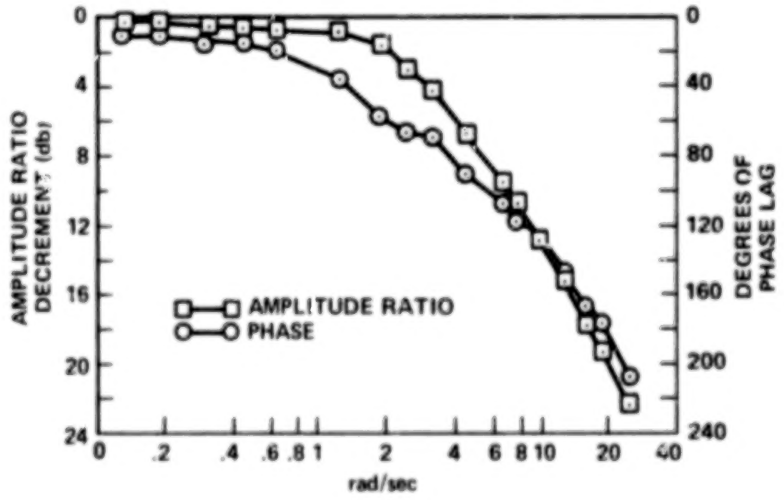


Figure 5.– G-seat frequency response characteristics.

The G-seat was mounted in the simulator cockpit as depicted in figure 6. The pilot could adjust the G-seat and the rudder pedals fore and aft to his liking. The simulator was a fixed base, visually equipped, fully instrumented, single-seat aircraft simulator with gull-wing access doors that remained closed during testing.

A modified camera model-board visual system generated the visual presentation. It was a six-degree-of-freedom system in which a television camera, mounted on a gantry, moved relative to a fixed-model board. The digital simulation computer translated pilot-control system inputs into the appropriate camera movements so that the visual scene -- a landscape scene -- was compatible with pilot inputs and expectations. The visual scene was presented to the pilot by an uncollimated cathode-ray tube display situated in the forward cockpit window. The display device shown in figure 7 was mounted 68.7 cm from the pilot's eye point and created viewing angles of 32° vertically and 41° horizontally.

The aircraft simulated during testing was a high-performance (Mach 1+) dual-engine jet aircraft. Although the simulated aircraft required little stick movement to generate sizeable roll or pitch changes, the aircraft was essentially stable. With a thrust-to-weight ratio greater than 1.0, the aircraft could accelerate readily when given the proper throttle input. In essence, the simulated aircraft could perform a variety of high-speed, high-g maneuvers, creating the proper environment to subjectively analyze and evaluate G-seat cueing.

Subjects

The subjects were 5 pilots from George AFB, California, a Tactical Command base. Two (P#1 and P#2) were currently flying the F-105 aircraft and three (P#3, P#4, and P#5)

Figure 6.– G-seat cockpit configuration.

Figure 7.– Cathode ray tube installation.

were flying the F-4 aircraft. The group averaged 1921.4 hr of flying time as aircraft commanders.

The study depended upon the ability of every subject pilot to intelligently compare the two types of G-seat cueing schemes presented to him in this experiment. To insure that each pilot was familiar with evaluating the relationship of seat cues with his perception of acceleration, a flight test program was conducted just prior to simulator testing. In the flight test program, every pilot, flying either an F-4 or an F-105 aircraft, flew four different high acceleration maneuvers like the ones performed in the simulation experiment (see Procedures). Shortly after each in-flight maneuver every pilot answered a questionnaire that required him to describe and evaluate a variety of acceleration-associated sensory events (e.g., buttocks pressure). Given this preparation, each pilot participated in the experiment.

G-Seat Cueing Schemes

During flight, the pilot experiences a number of seat oriented sensations, such as joint angle changes, skin pressure alterations, body angle movements, eye position changes, etc., all of which may amplify and define his sensations of acceleration. Such seat oriented physical events and their corresponding psychological events can be separated into two basic groups. One group contains those events associated with skin pressure changes and the other deals with body position changes that occur as the acceleration forces act upon the pilot's body. For instance, during a high -Z (+g) acceleration maneuver, the pilot's buttocks and thigh skin pressure increases markedly as the aircraft accelerates upward, pushing the seat firmly against the pilot's buttocks and thighs. Also, during that maneuver the pilot senses a body position change as he is compressed into the seat, lowering his eye position and slightly altering his hip joint and knee angles.

The most natural G-seat cueing scheme would generate stimuli relative to skin pressure changes and to body position changes. However, the G-seat has limitations which predispose it to relate to only one of those two sets of stimuli at a time. To simulate a given type of acceleration (e.g., -Z acceleration), the G-seat could be programmed either to drive the cells in the same direction as the aircraft acceleration force vector and simulate skin pressure changes, or to drive the cells in the opposite direction and simulate body position changes. Obviously, all of the G-seat cells cannot be driven in opposite directions simultaneously. Some guidelines need to be established regarding under what circumstances skin pressure changes are the most relevant cues, and what determines when body position cues are most important.

Therefore, two different cueing schemes were created. One was based upon body position changes (position) and the other upon skin pressure (pressure). Both cueing schemes commanded identical neutral (e.g., 1 g) positions in the seat back and pan. The seat back neutral position was 50% cell expansion for cells 17–25. The seat pan neutral position was a 50% cell expansion for cells 1–16, with a slight contouring for the buttocks and thighs.

The presentation of realistic Z-axis acceleration cues was complicated by the need to minimize the creation of inappropriate tuberosity-pressure cues (i.e., those pressure cues occurring at the base of the spine). During -Z (+g) accelerations those pressures increase markedly and during +Z accelerations they reduce substantially. The position logic was structured so that the pan cells supporting the tuberosities (cells 10, 11, 14, and 15) remained essentially unmoved to maintain normal (i.e.,

1 g) skin pressure, while the surrounding cells deflated as the -Z (i.e., +g) acceleration level increased and inflated as the +Z (i.e., -g) accelerations increased (fig. 8). The pressure logic was designed to change tuberosity pressure in a high-fidelity manner by having cells 10, 11, 14, and 15 inflate as -Z accelerations increased and deflate as +Z accelerations increased (fig. 9).

X-axis acceleration cues were less complicated. Under pressure logic guidelines cells 17–25 inflated as +X accelerations increased and deflated as -X accelerations decreased. The opposite occurred when the position logic was used (fig. 10).

Roll cues were generated by two sets of cells: right set cells 1, 6, 9, and 13; left set cells 4, 8, 12, and 16. Both cueing schemes required one cell set to inflate as the other set deflated. According to pressure concepts, the deflating set was on the seat pan side closest to the downward moving wing. The cell sets responded in a reverse fashion when the position logic was used (fig. 11).

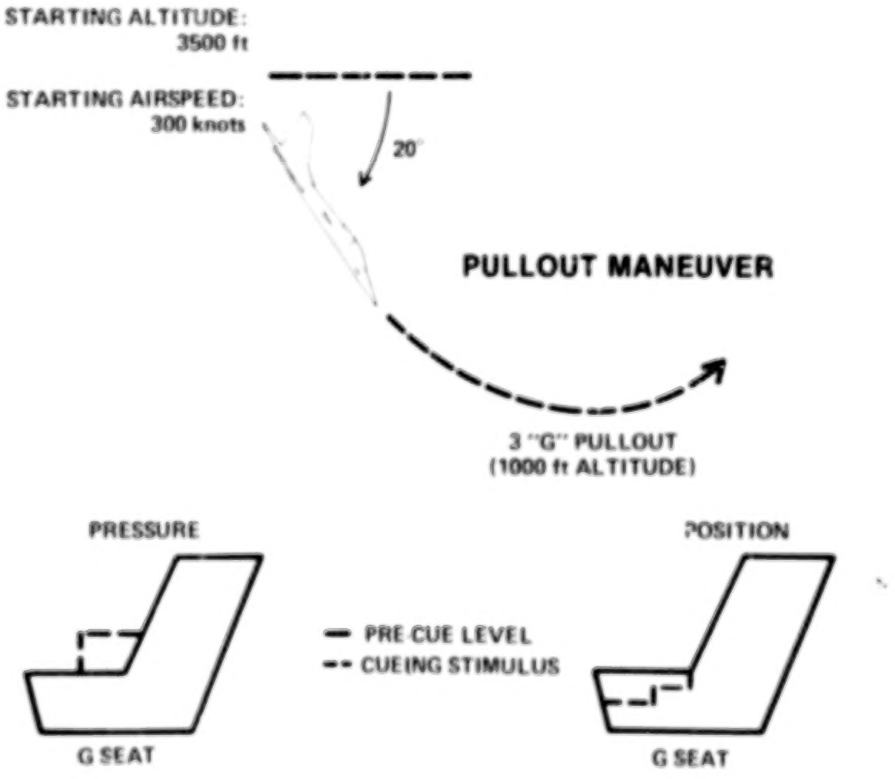


Figure 8.– Pressure vs position cueing scheme for -Z accelerations.

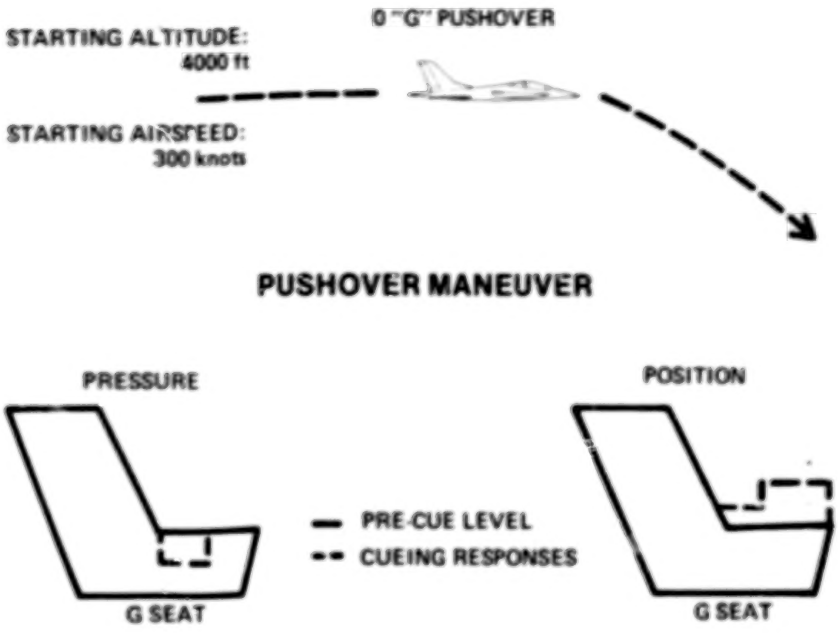


Figure 9.– Pressure vs position cueing scheme for +Z accelerations.

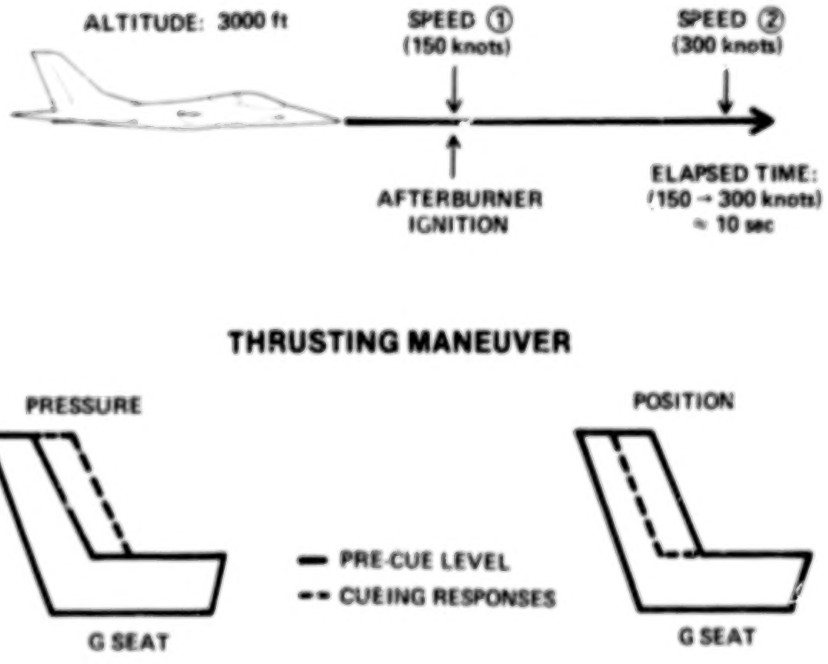


Figure 10.– Pressure vs position cueing schemes for +X accelerations.

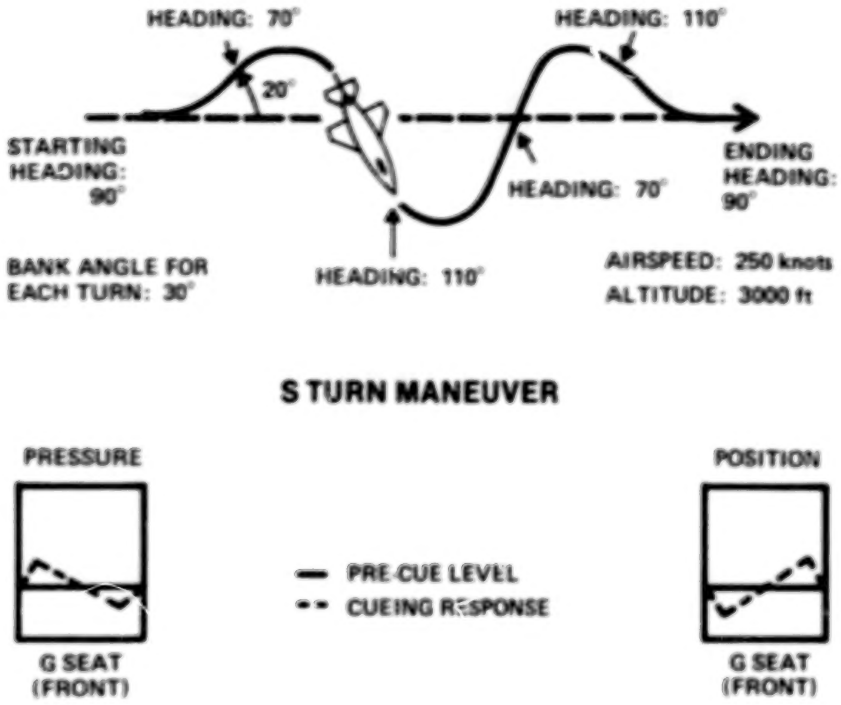


Figure 11.– Pressure vs position cueing scheme for roll.

Procedure

The experimental design required each pilot to fly the aircraft simulator for two three-hour sessions. Every pilot flew on two consecutive days, flying one session on each day. During any such two-day set, only one pilot served as a test subject. In the beginning of the first session, each pilot flew the aircraft simulator for 30 min without G-seat cueing, performing maneuvers of his choice. Thereafter, every pilot began G-seat testing, beginning initially with the four simple maneuver subsessions, the sequency of which was varied randomly across subjects, and all pilots ended testing with the complex maneuver. A given simple maneuver was designed to generate accelerations of only one type. The pullout (fig. 8) and the pushover (fig. 9) created –Z and +Z accelerations, respectively. The S-Turn (fig. 11) generated roll accelerations and the thrusting maneuver (fig. 10) developed +X accelerations. For a given simple maneuver, the G-seat was programmed using either cueing scheme to cue only the relevant accelerations. For example, during the pullout the G-seat presented only –Z acceleration cues. All the simple maneuvers were the same in that they were highly structured situations for contrasting G-seat position cues with G-seat pressure cues. During every simple maneuver subsession, the pilot flew the maneuver many times, taking great care to fly it the same way each time. Start points and initial conditions were identical from repetition to repetition, which, when coupled with the pilot's repeated performances, created essentially the same visual and instrument cues from trial to trial.

The complex maneuver (fig. 12) was different. This maneuver, always flown at the very end of testing, existed as a means of refining and evaluating the preferences the pilot had revealed during the simple maneuvers. Every pilot flew this maneuver and simultaneously received X axis, Z axis and roll G-seat acceleration cues. Each cueing scheme was designed so that the amount of G-seat cell

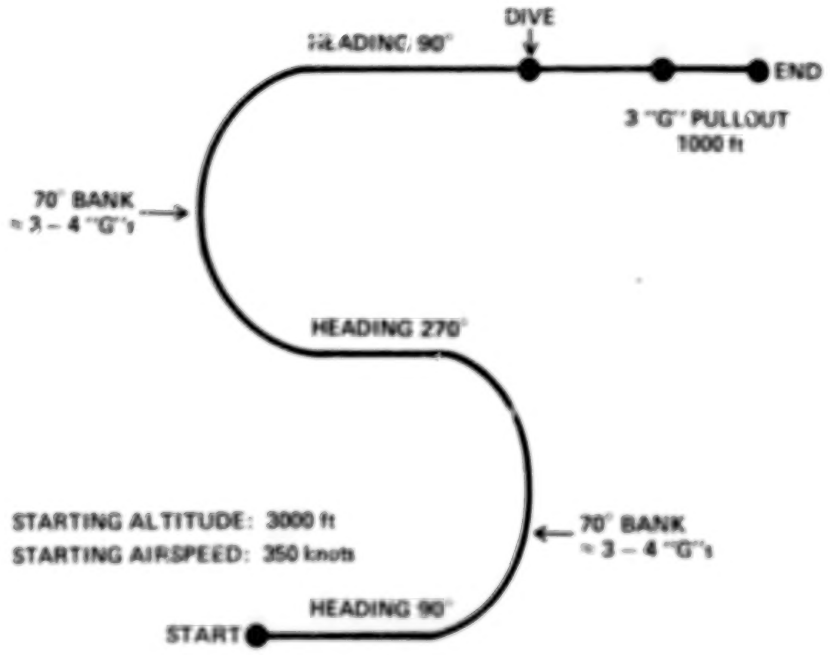


Figure 12.– Complex maneuver.

displacement used to cue a certain acceleration (e.g., +Z acceleration) could be varied according to, not only the level of acceleration generated during the maneuver, but also upon the gain:

$$K\ (\text{gain}) = \frac{\text{cm of cell travel}}{\text{cm/sec}^2 \text{ or rad/sec of aircraft movement}}$$

$$\text{cell displacement} = K\ (\text{acceleration})$$

A different gain could be created for +X, +Z, -Z, and roll acceleration cueing schemes.

According to the ascending single-staircase forced-choice methods used in this experiment, every pilot began each simple maneuver subsession at gain 1, which permitted minimum cell excursion and progressed through gain 2, 3, etc., each of which permitted progressively more cell excursion. At every gain each pilot flew four repetitions of the appropriate simple maneuver, receiving two pairs of trials. In the first pair of trials, both types of logic were presented, one on the first trial and the other on the second. After the second trial, the experimenter required the pilot to choose which of the two previous types of G-seat logics he most preferred to cue the accelerations of that maneuver and to rate the cues given on each trial using the rating scale shown in table I. In the second pair of trials at that gain level, the procedure was the same, after which the pilot then proceeded on to the next gain level in the sequence and repeated the same process. For a given simple maneuver, the sequence of gains and logic types was the same for all pilots and can be examined further by referring to table II.

TABLE I.– RATING SCALE

1. Optimum	Seat cues are highly realistic and definitely impart to the pilot an awareness of aircraft accelerations.
2. Near optimum	Seat cues are realistic and impart to the pilot an awareness of aircraft accelerations.
3. Suitable	Seat cues provide some realism and impart to the pilot some awareness of aircraft accelerations.
4. Near suitable	Seat cues could provide some realism and impart to the pilot some awareness of aircraft accelerations if some minor changes were made in the seat contouring.
5. Unsuitable	Seat cues cannot enhance realism and cannot cue acceleration.

Testing in a simple maneuver continued for a pilot until he reached criterion which occurred when he had selected the same logic type for three successive gain levels, and during said period, had rated the preferred type with the same numerical rating (see table I). Criterion was also reached when the pilot had selected the same logic type for three successive gain levels and had rated it initially with a certain numerical rating, subsequently using a greater numerical (less preferred) rating.

TABLE II.– GAIN SCHEDULES FOR SIMPLE MANEUVERS

Gain level	Pullout, cm/g	Pushover, cm/g	Thrusting, cm/g	S-turns, cm/rad sec^{-1}
1	0.13	0.13	0.25	0.15
2	.19	.25	.38	.25
3	.25	.32	.51	.38
4	.32	.38	.64	.51
5	.38	.51	.76	.64
6	.46	.64	1.02	.76
7	.51	.76	1.27	1.02
8	.57	.89	1.53	1.53
9	.64	1.27	1.78	2.04
10	.70	1.53	2.04	2.54

After the test flights for a simple maneuver were completed, the pilot answered the Post Maneuver Questionnaire shown in appendix B. Upon completion of the questionnaire, the pilot proceeded to another simple maneuver subsession until all four were completed. Thereafter he flew the complex maneuver four times and answered the End-of-Study Questionnaire (appendix B) after the fourth repetition.

RESULTS

For each simple maneuver subsession, the lowest gain level where a pilot rated his preferred logic with its lowest numerical (most preferred) rating was used as the preferred gain setting for that pilot for that maneuver. Across pilots, the average preferred gain and the range of preferred gains for the pullout, pushover, and thrusting maneuvers are, respectively: 0.41 cm/g, 0.32–0.51 cm/g; 0.74 cm/g, 0.38–1.27 cm/g; and 1.02 cm/g, 0.76–1.02 cm/g. Due to the inability to satisfy the criterion on the S-turn, no average preferred gain or range statistics can be given.

As shown in figure 13, four of the five pilots preferred the position logic as the cueing scheme for the pullout and pushover maneuvers. Although a pronounced group trend is shown, one pilot's (P#3) preference was opposite that of the group. For these two maneuvers this pilot emphatically

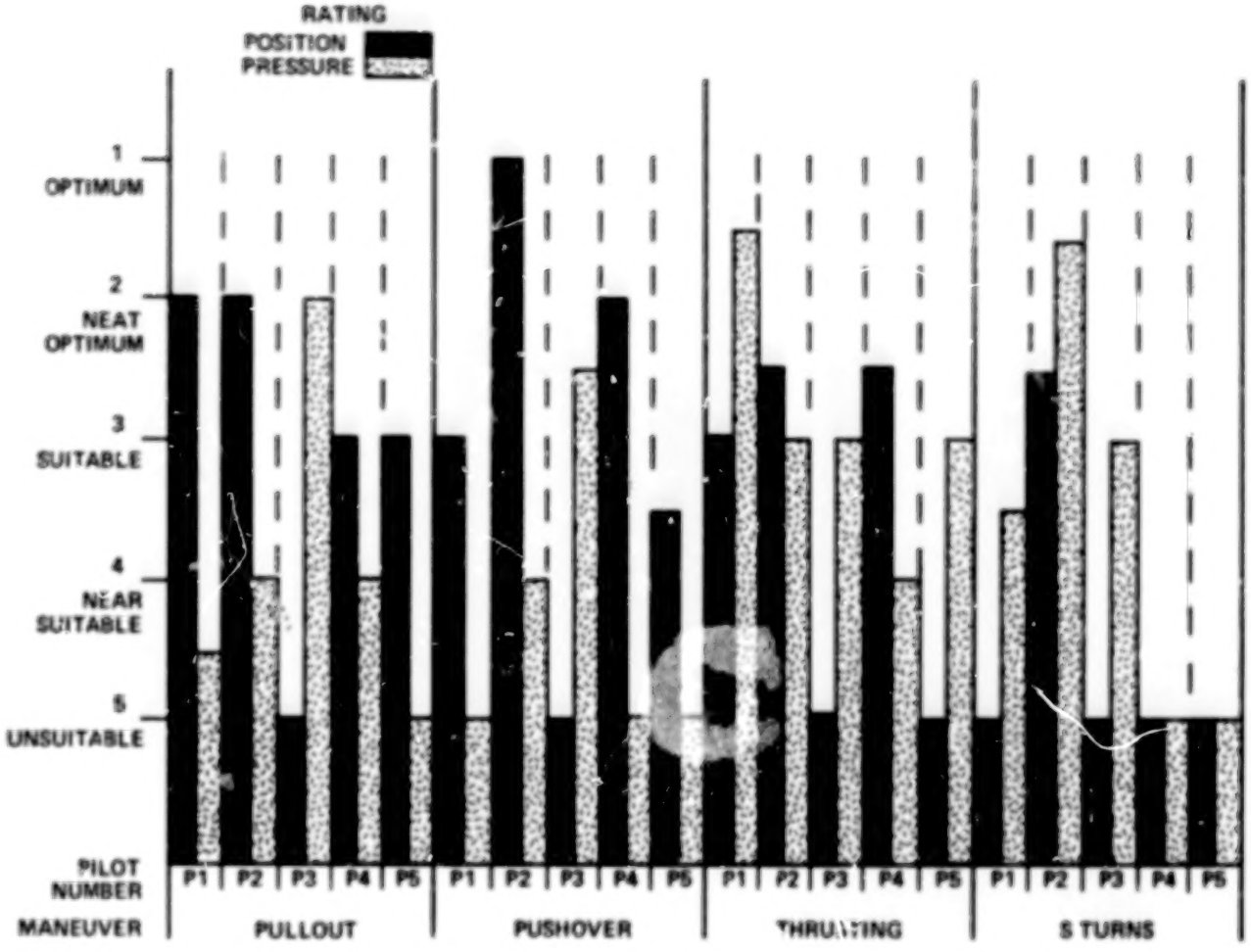


Figure 13.– Pilot preferences.

preferred the pressure cueing scheme over the position one. The presence of such a pronounced dichotomy suggests that, although a clearly identifiable group trend can occur, noteworthy individual differences can exist also.

The data for the thrusting maneuver (fig. 13) does not show as obvious a preference for one logic as did the data for the Z acceleration maneuvers. As shown in figure 13, three pilots preferred the pressure logic G-seat cues to simulate the +X accelerations of the thrusting maneuver, and the other two pilots selected the position logic cues as preferable. However, one of those two pilots rated the nonpreferred pressure logic cues as suitable. In total, four of the five pilots rated pressure logic cues as suitable or better, whereas three of the five rated the position logic cues as such. Further, regarding the less than suitable ratings that each logic was given, one of the five pilots rated pressure logic cues as near suitable, and two of the five rated position logic cues as unsuitable. Apparently, the pressure logic has slightly more potential to generate realistic +X acceleration cues and noticeably less potential to create poor +X acceleration cues.

The S-turn maneuver evaluation was unique (fig. 13). Four of the five pilots found some major weak points in both G-seat roll cueing schemes. Both schemes used some type of differential thigh

pressure in an attempt to induce the illusion of roll. Either type of differential thigh pressure was cited by pilots no. 1, no. 4, and no. 5 as only minimally important. Pilots no. 4 and no. 5, who rated both cueing schemes as unsuitable, remarked that during a roll the most noteworthy seat cues were Z acceleration cues, and verbally expressed an inability to relate to either type of G-seat roll cues. They further stated that for rapid rolls, lateral upper body movement was an important cue. Pilot no. 1, who once rated his preferred cueing scheme as near suitable, stated that ". . . unequal inflation of the seat is highly detectable and unrealistic to that encountered in flight." He further observed the failure of the G-seat to duplicate one important roll sensation, lateral upper body tilt. Pilot no. 3 was unable to relate to either type of G-seat roll cues at normal roll rates, verbally citing that only during high-roll rate or uncoordinated maneuvers did differential thigh pressure cues occur. He preferred G-seat pressure cues during rapid rolls. In general, however, it appears that neither roll cueing scheme was acceptable.

The results of the End-of-Study Questionnaire are incorporated in the Discussion section. Also contained in the Discussion section are the results of the complex maneuver performances.

DISCUSSION

The Post Maneuver Questionnaire results (appendix B) contain the explanations for each pilot's simple maneuver logic preferences. Reading these questionnaire responses reveals how individualistic was each of the pilot's preferences. Even those pilots who preferred the same cueing scheme to cue a certain type of acceleration, often did so for very different reasons. The Post Maneuver Questionnaire responses served as a valuable source of information for the experimenter and will greatly aid an interested reader in understanding the complex issues surrounding the creation of an "acceptable" G-seat cueing scheme.

The results of each simple maneuver will be discussed in separate subsections. The discussion in each one will attempt to suggest guidelines for writing an "acceptable" (i.e., best compromise) cueing scheme for the type of acceleration dealt with in that subsection.

Pullout

The pullout maneuver was always flown so that prior to the pullout, accelerations were essentially minimal. Subsequently, as the pilot pulled back on the stick, -Z accelerations gradually increased. The -Z acceleration increase caused the G-seat contour to change. The use of the position logic caused the G-seat pan cells to be deflated in response to the -Z acceleration increase, whereas the use of the pressure logic caused G-seat cells 10, 11, 14, and 15 to be inflated.

The four pilots who chose the position logic to cue the pullout maneuver did so for a number of reasons. All four in some way preferred and approved of the sinking sensation that the position logic created, but each emphasized that effect somewhat differently when making his evaluation. As appendix B reveals, three pilots (P#1, P#2, and P#4) related directly to the sinking sensation as a dominant cue, but one of those three (P#2) also cited that the sinking cue was detectable as his back slid downward while pressing against the seat back. He also cited that the sinking sensation was only a partial cue, with its influence diminishing rapidly above 2 g's. The fourth pilot (P#5)

mentioned the sinking sensation, but also liked the more dispersed skin pressure cues of the position logic, which may suggest a need to reduce the localized pressure cues of the pressure logic.

One weak point of the position logic was noted. As the level of -Z acceleration rose and the G-seat pan cells deflated, the deflation caused an initial and momentary decrement in skin pressure. This was disconcerting, since under the same circumstances in actual flight, a skin pressure increment would have occurred. In spite of this drawback, four of the five pilots rated position logic -Z acceleration cues as suitable or better. Apparently, they could ignore the initial anomalous skin pressure cues, and concentrate upon the realistic body position cues occurring thereafter.

To two of the four pilots who had preferred the position logic, a major shortcoming of the pressure logic -Z acceleration simulation was that it created an anomalous upward body movement cue. Although initial skin pressure cues were realistic, these pilots found that the subsequent upward body movement cues dominated their perception of the situation, and forced them to rate the pressure cueing scheme as near suitable or unsuitable.

However, one subject pilot (P#3) emphatically preferred the pressure cueing scheme to simulate -Z accelerations. Pilot no. 3 emphasized the moments when +Z accelerations had just begun to rise. If the G-seat stimuli occurring then were unrealistic, he rated that cueing scheme as unsuitable. If they were realistic, that established a positive effect that continued for him throughout the maneuver. With the strong point of the pressure logic being its ability to cause an increase in buttocks skin pressure during -Z acceleration onset, and with the weak point of the position logic being its inability to cause the same, pilot no. 3 consistently chose the pressure logic to cue -Z accelerations.

Group trends definitely exist for the pullout maneuver. Noteworthy divergences exist, also. Considering that the G-seat, when cueing -Z accelerations, cannot simultaneously generate realistic skin pressure cues and high-fidelity body position cues, writing an acceptable cueing scheme for -Z acceleration is, therefore, problematic. If the test group was representative of the high-performance aircraft pilot population, then designing a G-seat logic based upon position logic principles, would create cues unacceptable to some pilots. Yet, basing a logic upon pressure logic guidelines would apparently create an even more unacceptable simulation of -Z acceleration cues. Perhaps the most effective approach, considering the strength of the two group trends, would be to design a G-seat cueing scheme using position logic guidelines, especially to cue -Z accelerations, but with a concentrated effort at minimizing the anomalous cues that the position logic, in its present form, can create.

Specifically, when simulating -Z acceleration cues, lower only those cells not supporting the tuberosities, keeping cells 10, 11, 14, and 15 completely stationary. Perhaps the illusion of downward body movement would still be generated, while the disturbing initial negative pressure cues would be somewhat attenuated. A recent article (ref. 2) described a G-seat that used essentially that type of -Z acceleration. This device simulated -Z acceleration cues by keeping tuberosity support constant, and by varying buttocks support according to the level of -Z acceleration at that time. According to the author, a group of six test pilots flew a simulator equipped with this device and they unanimously approved of it as a means of cueing -Z accelerations.

Pushover

The pushover maneuver was always flown so that prior to when the pilot pushed forward on the stick, +Z accelerations were minimal. However, when the pilot pushed the stick forward, +Z accelerations rapidly increased. The -Z acceleration onset caused the G-seat pan cells, except cells 10, 11, 14, and 15, to be inflated in response to +Z accelerations; whereas, the use of the pressure logic caused cells 10, 11, 14, and 15 to be deflated.

As with the pullout maneuver data, an obvious group trend exists for the pushover maneuver data. Four of the five pilots chose the position logic cues to simulate the +Z accelerations generated during this maneuver. Two pilots emphasized the lap belt pressure cues, another related to shoulder harness cues, and a fourth referenced the general upward movement as the basis for his preference. One often cited drawback to the position logic simulation was that a disconcerting increase in buttocks pressure preceded the upward body movement.

However, one pilot (P#3) demonstrated a decided preference for the pressure logic cues to simulate +Z accelerations. In the initial portions of the pushover maneuver, the +Z accelerations were minimal and quite constant, but they began to increase markedly after the pilot pushed the control stick forward. As with the -Z acceleration maneuver, pilot no. 3 emphasized the G-seat cues presented just after he had moved the stick. G-seat cues occurring noticeably after +Z acceleration onset had little effect upon his rating. As a result, since the pressure logic generated more realistic +Z acceleration onset cues than did the position logic, he consistently selected the pressure logic cues as preferable.

Perfecting the simulation of G-seat +Z acceleration cues using position cueing scheme principles may prove to be more difficult. Three sensations dominate the perception of +Z accelerations: (1) the decrease in buttocks pressure, (2) the upward movement of the body, and (3) the increase in lap belt and shoulder harness pressure. The position cueing scheme duplicates the later two, while creating antagonistic buttocks pressure cues. The pressure cueing scheme, in contrast, can recreate a limited amount of buttocks pressure decrease, and does not generate the other two sensations at all. Unfortunately, there is no way in a fixed-base aircraft simulator to have a G-seat induce upward body motion without an increase in buttocks pressure. However, given that the existing position cueing scheme does not increase tuberosity pressure (cells 10, 11, 14, and 15 remain stationary throughout all +Z acceleration maneuvers), using a low gain level may still create enough upward body motion and avoid pronounced buttocks pressure increments. This scheme could, perhaps, be enhanced by combining it with a lap belt/shoulder harness contraction system. If, however, antagonistic buttocks pressure cues still proved problematic, another approach may be tried, a lap belt/shoulder harness contraction system could be integrated with the existing pressure cueing scheme for +Z accelerations. Of these two cueing schemes which employ a lap belt/shoulder harness contraction system, the former would produce some anomalous buttocks pressure cues, and the latter would completely fail to generate any realistic body position cues. The existing data does not allow one to accurately predict which of the two schemes would be preferable. However, on an intuitive basis only, it appears that the body position cue may be quite important, causing test subjects to prefer a scheme presenting realistic body position cues, even though that scheme would create some anomalous buttocks-pressure cues.

Thrusting

Pilots flew the thrusting maneuver in such a way that the X accelerations increased abruptly at afterburner ignition, and then failed to increase significantly thereafter. The position cueing scheme failed to generate realistic acceleration onset cues as the seat back cells deflated, causing a skin pressure decrement, not an increment. A favorable aspect of the position logic was that cell deflation subsequently recreated realistic upper body angle cues. On the other hand, the pressure cueing scheme presented realistic acceleration onset cues, as the abrupt cell inflation markedly increased skin pressure. However, as cell inflation progressed, the upper body was forced forward eventually inducing an unwanted sensation.

The strengths and weaknesses of each logic are the same as they were when those logics were used to cue Z accelerations. But, pilot preferences were different. Pressure logic cues were slightly more preferred to cue the X accelerations. Although the X- and Z-axis acceleration maneuvers did generate accelerations along different axes, there was another basic difference between the X-axis acceleration and the Z-axis acceleration maneuvers. The acceleration changes for both Z-axis acceleration maneuvers were relatively gradual, whereas those for the X-axis maneuvers were very abrupt. The change from gradual acceleration changes to abrupt ones (i.e., from low-frequency acceleration changes to high-frequency changes) apparently could have caused a shift in emphasis from the slower developing body position cues to the quickly created skin pressure cues. Perhaps, then the preference for the position logic during the Z acceleration maneuvers may not have been due to the situation that body position cues are most indicative of Z-axis acceleration changes, but that such cues are most indicative of *low-frequency* Z-axis acceleration changes.

The possible relationship between the frequency of acceleration change and the type of G-seat cueing scheme suggests that designing appropriate G-seat cueing schemes might be even more complex. Before selecting a logic type for each dimension (e.g., Z axis), the frequency characteristics of the tasks cued by that dimension's acceleration cues must also be considered. Further complicating the issue is that this G-seat design has certain frequency limitations, expecially at values exceeding 3.0 rad/sec (ref. 3). Given that low-frequency cues would be needed for Z-axis accelerations, and that high-frequency cues would be needed for X-axis accelerations, the following situation might occur: a fixed base G-seat simulation of a high-performance aircraft would require position logic guidelines for Z-axis cueing, a pressure logic format for X-axis cueing, a low pass filter on the Z axis (< 1.5 rad/sec) and an X-axis filter attenuating signals at values less than 1.5 rad/sec and greater than 6.0 rad/sec. It might also be feasible to cue high-frequency Z-axis cues using a pressure format which could be implemented using a high-pass filter (> 1.5 rad/sec).

S Turn

Regarding the S-turn data, it appears that the G-seat's potential to generate high-fidelity roll sensation is limited, partly because for normal roll rates there appears to be very, very few noticeable roll specific seat contour changes. During a normal roll rate pilots describe that upper body tilt and differential thigh pressure cues were minimal and that $-Z$ acceleration cues (e.g., a uniform buttocks pressure increase, a lowering of body position) predominated. The close relationship between aircraft bank angle and Z-axis acceleration changes apparently exerts a pronounced effect upon the pilot's body sensations during normal roll rate maneuvers. Secondly, the G-seat cannot induce a significant and timely upper body tilt cue. Such a cue, as pilot no. 3 remarked in

his Post Maneuver Questionnaire, can occur only during rapid roll maneuvers. Thus, given a lack of roll specific seat contours for normal roll rates and the inability of the G-seat to generate the significant cue of a rapid roll maneuver (i.e., upper body tilt), apparently the G-seat cannot induce the roll illusion, at least for a fixed-base high-performance aircraft simulation.

An acceptable roll cueing scheme for all roll rate maneuvers might be predicated upon the interdependency of bank angle and Z-axis accelerations. The G-seat can cue, to some extent, Z-axis acceleration changes, as shown by the favorable responses to G-seat stimuli for the pullout and pushover maneuvers. Via a G-seat position cueing scheme for Z accelerations, the G-seat could provide the pilot with some useful information as he performs a roll maneuver. The pilot, knowing he has just rolled the aircraft, would interpret G-seat Z-axis acceleration cues as indicators of his bank angle and rate of turn. Those same G-seat cues would aid a pilot performing a maneuver like the pullout by helping him anticipate his aircraft's airspeed and angle of attack.

Given a situation in which the pilot is seated many feet from the aircraft's center of gravity, G-seat pitch cues may be no different than those for Z accelerations and, therefore, practical. However, cueing schemes for lateral accelerations (Y) and yaw may be as difficult to implement as a roll cueing scheme. In flight, Y and yaw accelerations generate some lateral body movement, which would be difficult to create with G-seat stimuli. Only some type of seat pan tilt and/or seat back rotation could be generated, and such stimuli would not cause the appropriate lateral body motion cue. G-seat stimuli could create appropriate pressure cues, but in light of the pilot opinion regarding G-seat roll cues, G-seat pressure cues may not be able to induce the yaw or lateral acceleration illusion.

Complex Maneuver

In general, the pilot's responses to the questionnaire following the complex maneuver (see appendix C) were favorable with some reservations. This favorable response indicates that determining the gain and logic schedules from simple maneuvers can result in acceptable and perhaps optimum gain and logic schedules for multidegree-of-freedom simulations. It must be remembered that the gain and logic schedules were optimized for each pilot from the simple maneuver data. Only one pilot indicated that he thought the pressures created during the simulation of the $-Z$ acceleration were a little high. Two of the pilots commented on the inability of the G-seat to produce prolonged acceleration cues. Therefore, the G-seat may provide low-frequency cueing information, though it apparently will not provide very low-frequency information.

CONCLUSIONS

Specific implications of the data are:

1. The choice of G-seat logic, pressure or position, depends on the individual and the type of maneuver.

2. The G-seat may require filters similar to those used with motion systems, with the pressure logic cueing high-frequency cues and the position logic presenting low-frequency cues.

3. In its present form the G-seat does not provide the upper body lateral pressure or position information necessary for roll or lateral acceleration cueing.

In general, the data indicate not only that writing an "acceptable" cueing scheme would be quite difficult, but that such a cueing scheme may be inadequate and therefore limit the cueing capabilities of the G-seat.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., 94035, April 5, 1978

APPENDIX A

G-SEAT LOGIC AND CELL ACTUATION

Program as set up can drive the seat according to two philosophies. The first philosophy (position) can be selected by setting the following variables to their corresponding values.

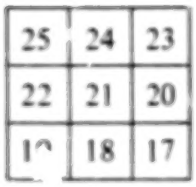
OPT = -2.54 cm (controls roll)
PHILOX = 2.54 cm (seat back - X axis cues)
PHILOZ = 2.54 cm (seat pan - Z axis cues)

The second (pressure) is set as follows:

OPT = 2.54 cm
PHILOX = -2.54 cm
PHILOZ = -2.54 cm

Furthermore, there are separate gains associated with each of the G-seat cues, roll, X, and Z. They are GPB, GX, and GZ, respectively. Setting any of these to 0.0 will block out any movement of the seat in the corresponding axis. GPB, GZ, and GX specify the gain per gravity in the specified axis. Thus, GX = 0.13 would move the appropriate seat cells 0.13 cm for each g of thrust. Similarly, GPB specifies movement cm/rad sec^{-1}. Note that roll cueing was based upon roll velocity, not on roll acceleration.

X-AXIS CUES



(Bottom)
Seat Back

+X Acceleration

Position	Pressure
Cells 23 and 25 remain stationary.	Cells 23 and 25 remained stationary.
Cells 17, 18, 19, 20, 21, 22, and 24 moved aft as per the gain.	Cells 17, 18, 19, 20, 21, 22, and 24 moved forward as per the gain.

-X Accelerations

Position	Pressure
Opposite of position +X cues.	Opposite of pressure +X cues.

Z-AXIS CUES

16	15	14	13
12	11	10	9
8	7	6	5
4	(Front)		1

Seat Pan

+Z Accelerations

Position

Cells 10, 11, 14, and 15 move downward a maximum of 0.10 in. regardless of the gain.

Cells 1 and 4 remain stationary.

Cells 5, 6, 7, 8, 9, 12, 13, and 16 move downward as per the gain setting.

Pressure

Cells 1, 4, 5, 6, 7, 8, 9, 12, 13, and 16 remain fixed.

Cells 10, 11, 14, and 15, move upward as per the gain.

-Z Accelerations

Position

Cells 1, 4, 10, 11, 14, and 15 remain fixed.

Cells 5, 6, 7, 8, 9, 12, 13, and 16 move upward as per the gain.

Pressure

Cells 1, 4, 5, 6, 7, 8, 9, 12, 13, and 16 remain stationary.

Cells 10, 11, 14, and 15 move downward as per the gain.

ROLL CUES

16	15	14	13
12	11	10	9
8	7	6	5
4	(Front)		1

Seat Pan

Roll Left

Position	Pressure
Cells 6, 7, 10, 11, 14, and 15 remain stationary.	Cells 6, 7, 10, 11, 14, and 15 remain stationary.
Cells 1, 5, 9, and 13 move upward and cells 4, 8, 12, and 16 move downward as per the gain setting.	Cells 1, 5, 9, and 13 move downward and cells 4, 8, 12, and 16 move upward as per the gain setting.

Roll Right

Position	Pressure
Opposite of position logic for roll left.	Opposite of pressure logic for roll left.

APPENDIX B

POST MANEUVER QUESTIONNAIRE

1. Why did you make the selections that you did? Cite the strong and weak points of each of the G-seat drive philosophies that you received.

END-OF-STUDY QUESTIONNAIRE

1. How did G-seat cueing affect the realism of the simulation during this last series?

2. How did G-seat cueing affect your knowledge of aircraft attitudes and accelerations?

APPENDIX C

POST MANEUVER QUESTIONNAIRE RESPONSES

Pullout

Why did you make the selections that you did? Cite the strong and weak points of each of the G-seat drive philosophies that you received.

P#1 Body movement; best at G5 (gain no. 5) because body movement continued downward. When using inflation of the seat to simulate positive g, the cues are conflicting. Although one senses the increased pressure on the buttocks, the pressure exerted on the seat straps by the upper body makes one also sense a negative g condition. I think the negative g sensation is the stronger of the two sensations.

P#2 The deflation method was much better. The sinking in the seat feeling and also the movement downward of the back against the back of the seat. It definitely felt like pulling a couple of g's but not like 3 g's. At the higher g's (3–4) pressure sensed on the rest of the body is important.

P#3 The easy part of the selection process was eliminating the pullouts where the seat deflated, causing less pressure on the buttocks. The programs that gave a definite pressure throughout the maneuver were easily identified. I feel that evaluation number 13 (trial number) was the best simulation, followed closely by number 18 (trial number) because of the constant pressure throughout the pull. In some cases the pressure was there but it was not intense enough. In other cases after initial pressure was felt, it bled off (although that may have been due to easing off on back pressure). No weak points.

P#4 I preferred the deflating philosophy. It gave a feeling of sinking in the seat as g was applied, which is realistic. The disadvantage of this philosophy is that it does not provide the accompanying increase in seat pressure. However, I feel the sinking feeling is a better cue in this case.

The inflating philosophy provides the feeling of increasing seat pressure, but also gives a lifting sensation which is unrealistic in this maneuver. Overall, I prefer the sinking sensation, even at the expense of the presence of seat pressure.

P#5 Seat pressures as g increases should be stronger but widely dispersed. The decreased concentration of pressure more *closely resembled the actual feeling* experienced in the aircraft. The increased pressure runs were too concentrated and did not closely resemble the actual feeling. The decreased pressure concentration would better approximate actual conditions if thigh pressure could be increased while allowing the majority of the seat to sink.

Why did you make the selections that you did? Cite the strong and weak points of each of the G-seat drive philosophies that you received.

P#1 The only cue from the seat that could impart a sense of negative g was lap belt and shoulder strap pressure on the body. There are other cues in an actual aircraft that the seat in its present form cannot duplicate. For example, the limbs begin to float, a lightness in the stomach is felt, and the buttock pressure to near zero regardless of the two modes of operations that are being used.

The gain levels used so far do not impart a cue strong enough to simulate the near zero condition in flight. If more pressure/inflation of the seat were used in conjunction with some downward pressure of the straps on the shoulders, perhaps by designing a new feature in the present seat, the negative g sensation would be stronger. This seems necessary to me in light of the absence of the other cues that are present in the actual aircraft.

P#2 The deflation method did not feel realistic except at low pushover rates (0.5 to 1.06). At higher rates (0.5 to 0.0) the inflation method felt better. Upper press on seat belt used as main cue. Trial 32 seemed about the best. Trial 36 was bordering on too much inflation.

P#3 Again there was no doubt between the increase or decrease of buttocks pressure. Of the two types of maneuvers tested today, the cues for the positive g pullout are stronger than the cues for the pushover. I felt that the *initial magnitude* of the seat cushion deflating gave the stronger feeling of the decrease in g caused by the pushover. I feel that test number 38 best simulated the decrease in g by the initial magnitude of the seat reaction.

The inflation of the seat creates increased buttocks pressure as if pulling positive g's, while the deflation decreases buttocks pressure as if being lighter in the seat due to a decrease in g.

P#4 I preferred the lap belt pressure philosophy until the seat pressure became such that the subtlety of the feeling was lost. At the proper onset rate, the seat provided a feeling of lap belt pressure that was similar to an unloaded condition. The disadvantage of this philosophy is the seat pressure that is felt, which is not present in the aircraft. The light seat philosophy did provide an unloaded sensation initially, but the sensation was not sustained throughout the maneuver. The disadvantage of this philosophy was the absence of lap belt pressure.

P#5 The first selections were made because upper body movement was closest to that actually experienced even though increased buttocks pressure was exactly opposite. As buttocks pressure continued to increase, upper body movement became less important and perception began to primarily focus on the points of most pressure. The final runs emphasized decreasing seat pressure but upper body movement was in the wrong direction. The actual feeling should be one of upper body moving up and continued decrease in seat pressure.

Why did you make the selections that you did? Cite the strong and weak points of each of the G-seat drive philosophies that you received.

P#1 Both philosophies give a sense of acceleration, however, my preference seems to be with increasing pressure to the back. In actual flight, my body senses respond to heavier back pressure more than to seat movement (i.e., rearward body movement in the seat). In addition, the philosophy that I selected also gives a hard thrust to the lower back during afterburner light which, in turn causes my head to rotate backwards with a snap much like that encountered in actual flight.

P#2 Cell deflation was preferred, but at higher intensity levels I almost went for the inflation.

In most tests from one to the other, there didn't seem to be that much difference and choice was from just a general feeling.

In the deflation method, it deflated to the point of feeling the back of the seat underneath and this detracted somewhat.

Perhaps a combination of inflation (tied to afterburner) and deflation (tied to acceleration) would work better.

Performed deflation better due to the idea of the body sinking into the seat rather than the seat pushing up on the body. In aircraft the body sinks into the seat and even though there is a push on the body, the body movement seems more important.

P#3 The seat inflation, causing the increased pressure on the back, more closely resembled the feeling of being forced back against the seat. I preferred the pressures on number 14 and number 20 because of an even distribution across the back. The tests beyond number 20 seemed less realistic because the upper back was receiving more of the pressure than the lower back.

When the seat was deflated upon initiation of afterburner, I felt as if I were moving away from the seat as in decelerating. The decrease in pressure on the back was far more influential as a cue than the actual backward movement permitted by the seat deflation.

P#4 I preferred the deflation philosophy, which gave a feeling of moving aft during the acceleration. The feeling needs to be a little more abrupt to accurately simulate an A/B ignition, however. The disadvantage of this philosophy is the absence of seat pressure on the back, however, the more important cue is the feeling of rapid movement aft, which is simulated by the deflation philosophy.

The inflation philosophy provides a feeling of pressure on the back, but forces the body forward during A/B initiation, which is unrealistic.

P#5 All selections applied initial pressure at AB light vs pressure relaxation. This initial pressure closely resembles the feeling during actual AB light. The continuous pressure during

acceleration is too strong compared to the actual feeling. The pressure should gradually reduce after a sharp pressure increase as AB lights. The body angle should go aft, as time after AB light increases.

S-Turns

Why did you make the selections that you did? Cite the strong and weak points of each of the G-seat drive philosophies that you received.

P#1 I selected the philosophy that uses inflation of the seat on the side opposite the direction of roll, because it gave me a greater sense of tilting than the other philosophy. For instance, a left roll required a lift on the right buttock to simulate a left tilt. When the opposite occurred, the reaction gave the sensation of a roll opposite to the real direction. The shortcomings of both philosophies is that the feeling of unequal inflation of the seat is highly detectable and unrealistic to that encountered in flight.

Also, there is a sensation encountered in flight that cannot be accurately duplicated in the seat. During the initiation of a roll, the upper portion of the body will tend to, at first, move in a direction opposite the roll due to upper body inertia, that is, left roll, upper body initially moves right. This inertia is quickly overcome by the roll and the sensation is only momentary. Therefore, the philosophy that I did not select emphasizes this sensation which is unrealistic because it prolongs the feeling longer than actual flight.

P#2 Turns felt better with seat pushing on body rather than body pushing on seat.

Both methods felt better as intensity was reduced but there was still too much for very small stick movement.

Seat reaction to start of a roll is good, but when a roll is stopped there is too much opposite seat reaction.

P#3 The data gathered on the first 10 S-turns may appear erratic as I was trying to second guess the seat. All decisions from gain level II on pressure I felt confident of.

When actually flying the aircraft, there is no apparent transverse g felt in the cockpit unless faster than normal roll rates are used, or the pilot is not coordinating aileron and rudder in the turn.

During the last 20 rolls I used a quick roll rate and felt that the seat inflation opposite the turn best simulated the lean away from the turn (i.e., left turn, increased pressure, or inflation of the right side of the seat). Since we are talking about a very small amount of g changes in the turn, I felt that the gain toward the end of the series was too great.

P#4 In this maneuver, I could not relate any of the seat cues to those I experienced in the aircraft.

Rather, during an aggressive roll into a level turn, there is a momentary unload to enhance the roll rate and maintain altitude, followed by a reapplication of g to maintain altitude and bank

angle. As best I can recall, pressure distribution changes between the buttocks are not a cue for this maneuver.

Additionally, an agressive roll rate will tend to thrust the upper body in the direction opposite the roll rate until coordinated flight is re-established in the turn.

P#5 The difference between the two choices is minute. The selections made were based on the correct body movement even though the seat pressure may have been opposite that which would actually be experienced. The primary sensory perception for this maneuver would be head movement and other forces/pressures would be insignificant.

APPENDIX D

END-OF-STUDY QUESTIONNAIRE RESPONSES

How did G-seat cueing affect the realism of the simulation during this last series?

P#1 G-seat cueing definitely enhances realism during simulator flights. G-seat response during stick inputs was effective in simulating the acceleration forces of flight. A person would have a relatively good feel for an aircraft's performance and his own sensations during flight, after having made several practice flights in the simulator, and even before actual aircraft flight was performed.

In this last series of maneuvers, the only weakness I noted was the loss of g sensation during a prolonged g maneuver. It should be noted that I also feel that the seat is relatively realistic but is not to be considered a near perfect simulator. Other cues from the body such as limbs and internal body tension are obviously lacking.

P#2 Cueing added considerably to realism. It especially helped on control of the aircraft.

I think the simulated aircraft was over reactive versus the amount of control input. However, the seat seemed to follow what the instruments were showing.

This over reaction on the part of the aircraft made the ride rather bouncy and seemed to make the coordination between seat reactions and stick inputs a little unrealistic.

P#3 Seat cueing was good. The inflation of the back pad should not have occurred when it did because there was no power change. The differential buttocks pressure may have been a little high during the last portion of the maneuvering.

P#4 I felt that G-seat simulation was good except in one area. During relaxation of g from 3 to 2, the G-seat gave unload cue, whereas the actual feeling would be one of constant positive g. I liked the simulation of g onset, however the cue goes away even though the g is maintained.

P#5 The seat pressures applied seemed to be the optimum of the ones chosen during the individual maneuvers. Realism is improved over stationary seat simulators but without upper body and head movement, actual conditions cannot be closely simulated.

How did G-seat cueing affect your knowledge of aircraft attitudes and accelerations?

P#1 G-seat cueing definitely improves my knowledge of aircraft attitudes and flight condition. Due to the additional cues which are interfaced with the visual cues of instruments and the outside world, the mental impression of attitude is reinforced and more convincing to the individual. It is especially convincing if the pilot has experienced all the sensations before, that is, more than a novice pilot.

P#2 With the seat cueing I was able to fly the aircraft and not rely so much on the instruments to determine accelerations. This was more noticeable in pitch rather than roll.

P#3 The important cues during the maneuvering were the unloading (0G) and the positive indications during the dive pullout (3G). The G once established in the turn was good but as mentioned on the reverse side of the actual cues of transverse G in the simulator was probably a lot higher than those of the aircraft. The cues for afterburner initiation were also very good.

P#4 Actual G forces (or G cues) do not provide an accurate indication of aircraft attitude. However, these are certain attitudes that could result in specific G cues. During the aircraft maneuvers that were flown, the G seat provided a realistic simulation, particularly of G onset during dive recovery and application of back pressure during a turn.

P#5 The G seat did improve simulation, however, a tradeoff had to be made between body movement and body pressures. In some cases, body movement was created by increasing/decreasing seat pressure which was exactly opposite of that experienced under actual conditions. Also, some cueing, although correct, is actually very insignificant to the proper sensing of a maneuver (i e., seat pressures during the turning maneuvers).

REFERENCES

1. Kron, G. J.: Advanced Simulation in Undergraduate Pilot Training: G-Seat Development. AFHRL-TR-75-59 (111), October 1975.

2. Ashworth, Billy R.: A Seat Cushion to Provide Realistic Acceleration Cues For Aircraft Simulators. NASA TM X-73,954, Sept. 1976.

3. Showalter, Thomas W.; and Miller, Robert J.: G-Seat System Step Input and Sinusoidal Response Characteristics. NASA TM-78478, May 1978.

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16. Abstract

This study is a comparison of two contrasting G-seat cueing schemes. The G-seat, an aircraft simulation subsystem, creates aircraft acceleration cues via seat contour changes. Of the two cueing schemes tested, one was designed to create skin pressure cues and the other was designed to create body position cues. Each cueing scheme was tested and evaluated subjectively by five pilots regarding its ability to cue the appropriate accelerations in each of four simple maneuvers: a pullout, a pushover, an S-turn maneuver, and a thrusting maneuver. A divergence of pilot opinion occurred, revealing that the perception and acceptance of G-seat stimuli is a highly individualistic phenomena. The creation of one "acceptable" G-seat cueing scheme was, therefore, deemed to be quite difficult.

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